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Assessing the need for repeatability in acquisition of time-lapse data

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Summary

There are several factors that affect the repeatability of 4D(time-lapse) seismic data.

One of the most significant factors is the repeatability of the acquisition, particularly the locations of the sources and receivers. It is important to repeat the source-receiver locations, used during the baseline survey, in the monitor or repeat survey.

Also, it is essential that the stacked data volumes used for time-lapse analysis are created using the same offset ranges for each survey. This condition is crucial in order to be able to produce an image of the same location over a period of time and enhances proper reservoir characterization.

The cost of repeating the seismic acquisition is very expensive, as often times, the receiver array has to be left at the same location over the period for which the data will be acquired. In other words, it is important to repeat the acquisition geometry as much as possible. In this talk, we investigate the results of changing the acquisition geometry, by a random placement of the receivers for both the baseline surveys and newer (monitor) surveys. Results show that we are still able to observe any time-lapse effects from the proposed acquisition geometry. Our experiments have been performed on a synthetic model.

Introduction

A time-lapse seismic survey compares two or more seismic surveys at different times. The goal is to observe any changes in the reservoir. These changes, if any, are known as time-lapse or 4D changes. A fundamental step in being able to detect these changes is to be able to repeat the acquisition process. Using the same types of seismic sources and receivers, and by acquiring data in the same direction and keeping the spacing between receivers as in the baseline survey, one aims to repeat the survey. However, factors such as topography, water currents, weather, etc. make it practically impossible to replicate a survey.

Time-lapse seismic studies have been carried out with emphasis on repetition of the survey. (Ross and Atlan (1997); Porter-Hirsche and Hirsche (1998).). These studies have shown tests that could be performed to assess repeatability, by using source-receiver coordinates and recording geometries as constants. In these studies, and in most time-lapse studies, the data is regularly sampled during the base survey and repeat surveys.

Compressed sensing, (Donoho(2006); Candes et al. (2006)) is a new theory which proposes randomized sampling. This random sampling has been applied to acquisition of seismic data (Moldoveanu (2010)) and by virtue of the requirement for obtaining time-lapse seismic data, the randomized sampling would create spurious artifacts in time-lapse processing, which might mislead unsuspecting interpreters.

Also, using the principle of Compressed sensing, Hennenfent and Herrmann (2008) proposed a randomized sampling strategy for seismic data acquisition and reconstruction of seismic wavefields.

Using their proposed sampling technique, we present some initial results of how randomized sampling will affect signals in 4D and we assess the effect of repeatability of the acquisition geometries. We will compare results with regular or periodic sampling for a fixed number of sources and receivers.

Method

Our approach entails acquiring synthetic seismic data, given a velocity model and acquisition parameters. After data acquisition, we use a frequency modeling algorithm to create reverse time migrated (RTM) images of the observed data.

Since we are dealing with a baseline and a monitor velocity model, we will also require a background velocity, for imaging.

The velocity models used in our experiments are shown in Figure 1 and Figure 2.

Data Acquisition

Given the velocity models, first, we generate synthetic data from the baseline model and monitor model, by using an acquisition geometry in which receivers have been sampled regularly over a defined offset. Then we use a different geometry in which the receivers are also regularly sampled, to generate data. In both cases, the number of receivers is constant and the spacing between receivers is also constant. The main difference is a shift in the array. Data obtained using this sampling scheme is termed *regularly sampled* data.

Secondly, we repeat the above experiment by using a geometry in which the receivers have been sampled according to a uniform random distribution. We use the same number of receivers used for the regular sampling case. This is denoted as *uniformly randomly sampled* data.

Next, we use the approach of Hennenfent and Herrmann (2008) by designing a different randomized geometry from a distribution – which gives us a *jittered randomly sampled* data.

Imaging

Having obtained synthetic data, we use our frequency modeling algorithm to generate RTM images of each data set, using the respective geometries.

Taking the background velocity as constant, we generate RTM image for the baseline model using a specific acquisition setup, then using the same setup, we generate RTM image for the monitor velocity model, and we plot the difference between the two images. This reveals the result of repeating the acquisition. Next, we use a different geometry (regular or random) to generate RTM image for the monitor velocity model, and we also compute the difference from the baseline image using a different geometry. This shows the effect of not repeating the acquisition.

We repeat the entire acquisition and imaging procedure for all the different acquisition setups.

Results

The results are shown in Figures 3, 4 and 5 for the different sampling strategies. In each figure, we show the difference between baseline and monitor images by using the same acquisition and by using different acquisition geometries. Clearly, we can see some spurious artifacts in the difference images when the acquisition is not repeated, in the case of sampling according to a uniform random distribution. Also, in the case of regular sampling, the size of the spatial shift between the baseline and monitor sampling may adversely affect the quality of the difference plot. For jittered randomized sampling, we are able to minimize the magnitude of any spurious events. In all cases, we are still able to locate the time-lapse change, which largely depends on the amplitude.

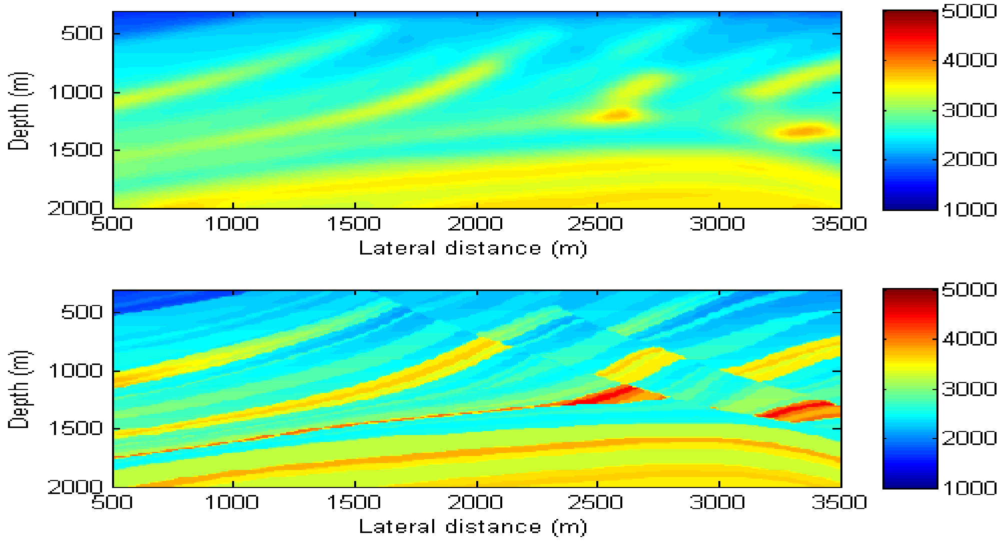

Figure 1: Top: Background Velocity model, Bottom: Baseline Velocity model

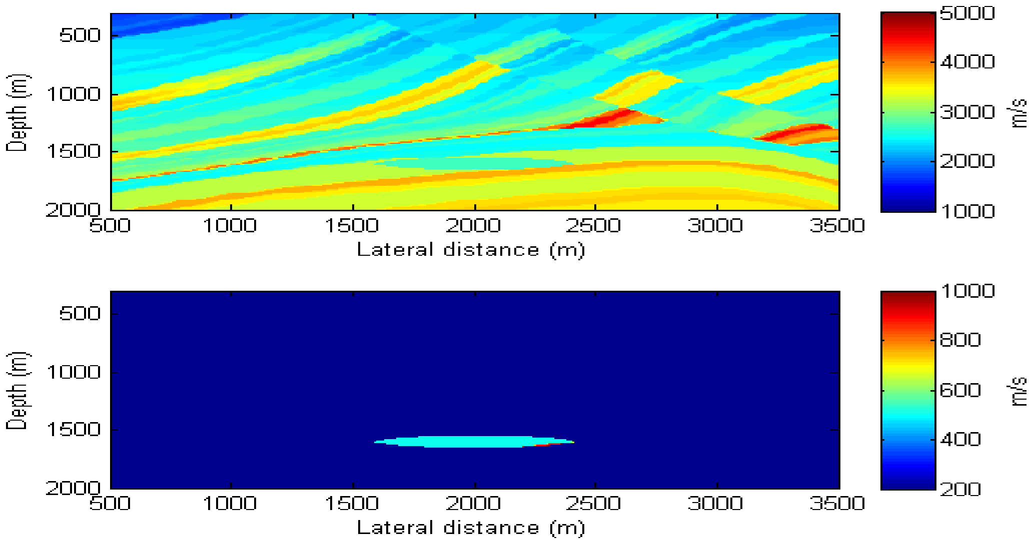

Figure 2: Top: Monitor velocity model, Bottom: Difference between baseline and monitor velocity models

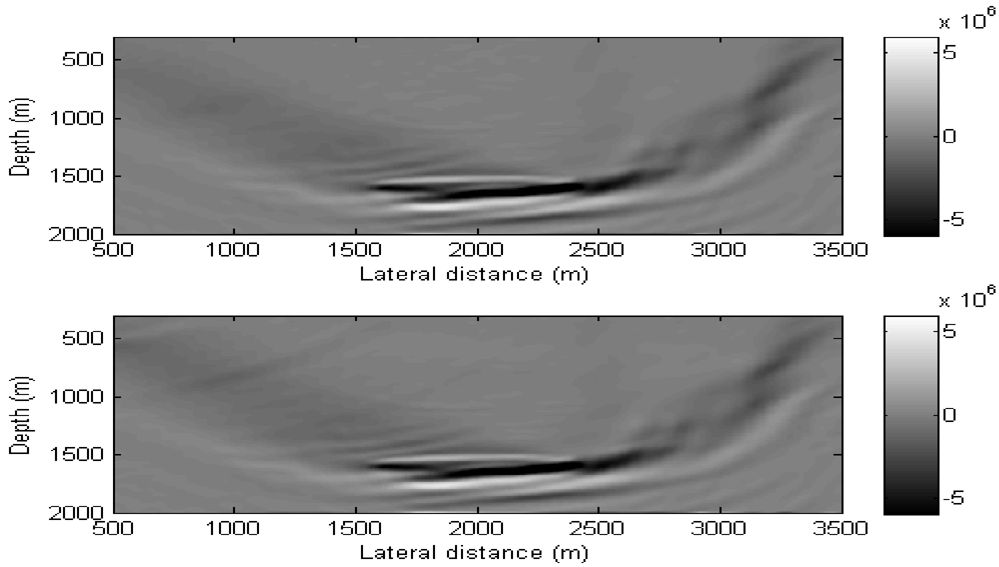

Figure 3: Top: Regular sampling with repetition; Bottom : without repetition (array shift of 20m)

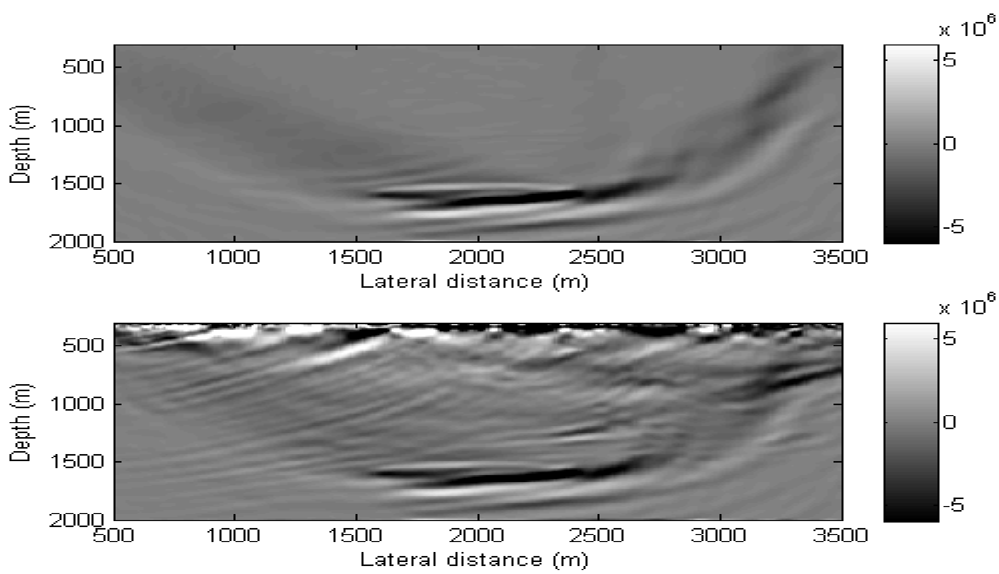

Figure 4: Top: Uniform randomized sampling with repetition; Bottom: without repetition

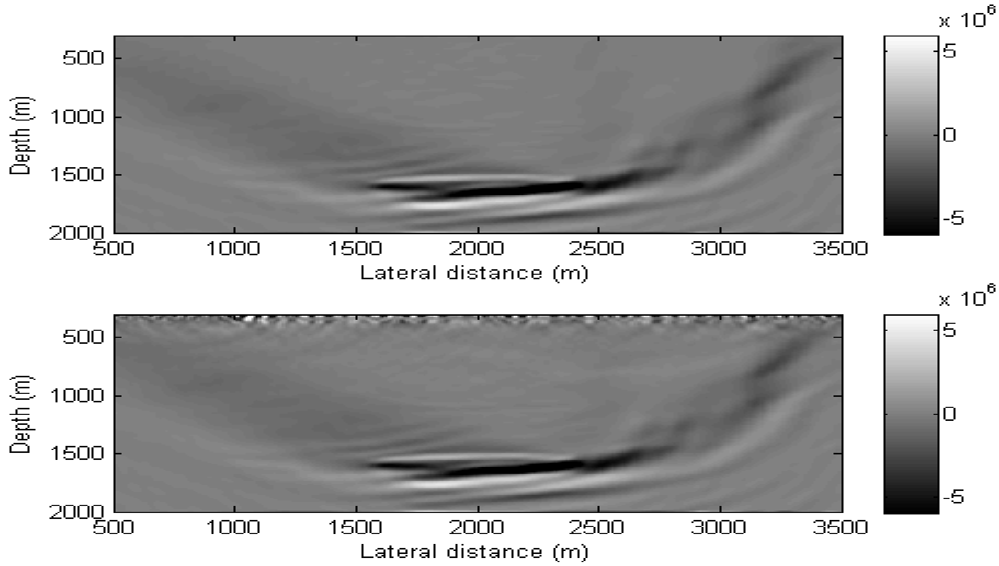

Figure 5: Top: Jittered randomized sampling with repetition; Bottom: without repetition

Conclusions

Repeatability of the acquisition geometry is very important for time-lapse studies, in order to resolve only time-lapse effects.

However, as long as we randomly sample according to a discrete random (jittered sampling) distribution, repeatability of acquisition may no longer be an issue to contend with during time-lapse surveys. We make this tentative conclusion on the assumption that the time-lapse data acquired using the proposed acquisition schemes, are processed in a similar way. Therefore, repeatability of the processing would greatly reduce processing artifacts in the difference images.

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